

XXIII. "Agricultural, Botanical, and Chemical Results of Experiments on the Mixed Herbage of Permanent Meadow, conducted for more than twenty years in succession on the same land." By J. B. LAWES, LL.D., F.R.S., F.C.S., and J. H. GILBERT, Ph.D., F.R.S., F.C.S., F.L.S. Received June 16, 1879.

(Abstract.)

In the experiments at Rothamsted with different manures, wheat has now been grown for thirty-six years in succession on the same land, barley for twenty-eight years, and oats for nine years. Somewhat in like manner, but with some breaks, beans have been grown over a period of more than thirty years, clover for many years, and "root-crops" (turnips, sugarbeet, or mangel-wurzel) also for more than thirty years. Each of these individual crops has exhibited certain distinctive characters under this unusual treatment. But, withal, those of the same natural family, wheat, barley, and oats, for example, have shown certain characters in common, those of the Leguminous family characters widely different, whilst the so-called root-crops, belonging to the Cruciferous and Chenopodiaceous families, have exhibited characteristics differing from those of either the Gramineæ or the Leguminosæ.

Compared with the conditions of growth of any one of these individual crops grown separately, those of the mixed herbage of grass land are obviously extremely complicated. Thus, it comprises, besides numerous genera and species of the gramineous and leguminous families, representatives also of many other natural orders, and of some of great prominence and importance as regards their prevalence and distribution in vegetation generally. And if, under the influence of characteristically different manuring agents, as has been the case, there have been observed notable differences in the degree of luxuriance of growth, and in the character of development, even between closely allied plants when each is grown separately, and much greater differences between the representatives of different families when so separately grown, might we not expect very remarkable variations of result, when different manures are applied to an already established mixed herbage of perhaps some fifty species growing together, representing nearly as many genera and more than twenty natural orders?

Such, far beyond what could have been anticipated, has been the case in the experiments described. So complicated, indeed, have been the manifestations of the "struggle" that has been set up, that, even after more than twenty years of laborious experiment, both in the field and in the laboratory, and following up both the botany and the chemistry of the subject, we can hardly claim to have yet done

much more than reach the threshold of a very comprehensive inquiry. Still, we hope to establish some points of general interest; and possibly to indicate promising paths of future research.

From the title of our paper, it will at once be concluded that the experiments were originally undertaken and arranged from an agricultural point of view. But, as experimenting on the feeding of animals soon led us into lines of inquiry of even more interest to the chemist, the animal physiologist, and the dietetician, than to the agriculturist, so the investigation of the effects of different manures on the mixed herbage of grass land has led us far beyond the limits of a purely agricultural problem, and has afforded results of more interest to the botanist, the vegetable physiologist, and the chemist, than to the farmer. Indeed, agriculture, the most primitive, and commonly esteemed the rudest of the arts, requires for the elucidation of the principles involved in its various practices, a very wide range of scientific inquiry; and the investigation of them may, in its turn, contribute facts of interest to the student of various and very distinct branches of natural knowledge.

It will be readily understood that, as a necessary foundation for the discussion of the botany and the chemistry of the subject, it will be essential first to put on record, and call attention to, what may be distinguished as the agricultural data. It is proposed, then, to arrange and consider the results obtained under the following heads:—

Part I. . . . . The Agricultural Results.

Part II. . . . . The Botanical Results.

Part III. . . . . The Chemical Results.

The general scope, objects, and results of the whole inquiry may be briefly indicated as follows:—

About seven acres in the park at Rothamsted have been set apart for the experiments, and divided into plots. Two of these have been left without manure from the commencement; two have received ordinary farm-yard manure, whilst the remainder have each received a different description of artificial or chemical manure, the same being, except in special cases, applied year after year on the same plot.

Referring first to the *Agricultural Results*, it may be premised that, *without manure*, the produce of hay has varied from year to year, according to season, from about 8 cwt. to nearly 39 cwt. per acre, and the average yield has been about 23 cwt. per acre per annum. On the other hand, the plot the most heavily artificially manured, and yielding the highest amount of produce, has given an average of about 64 cwts. of hay per acre per annum, with a variation from year to year from under 40 cwts. to nearly 80 cwts. Intermediate between the extremes here quoted, very great variation in the amount of produce has been exhibited on the other differently manured plots.

With these great differences in the amounts of produce the botanical character of the herbage has varied most strikingly. Thus, starting with perhaps fifty species on the unmanured land, any kind of manure, that is, anything that increases the growth of any species, induces a struggle, greater or less in degree, causing a greater or less diminution, or a disappearance, of some other species; until, on some plots, and in some seasons, less than 20 species have been observable, and on some, after a number of years, no more than this are ever traceable.

Even in the first years of the experiments it was noticed that those manures which are the most effective with wheat, barley, or oats, grown on arable land, that is, with gramineous species grown separately, were also the most effective in bringing forward the grasses proper, in the mixed herbage; and, again, those manures which were the most beneficial to beans or clover, the most developed the leguminous species of the mixed herbage, and *vice versâ*. It was further observed that there was great variation in the predominance of individual species among the grasses, and also among the representatives of other orders. And even in the second year the differences in the flora, so to speak, were so marked, that a first attempt at a botanical analysis of carefully taken samples of the produce of some of the plots was then made; in the third year more detailed separations were made; and, taking advantage of the experience thus gained, pretty complete botanical analyses have since been conducted four times, at intervals of five years, during the course of the now twenty-four years of the experiments; and on several other occasions partial separations have been undertaken. The character and tendency of the results so obtained may be very briefly indicated as follows:—

In the produce grown continuously without manure the average number of species found has been 49. Of these, 17 are grasses, 4 belong to the order Leguminosæ, and 28 to other orders. The percentage by weight of the grasses has averaged about 68, that of the Leguminosæ about 9, and that of species of other orders 23.

In the produce of the plot already referred to as the most heavily manured, and yielding the heaviest crops, the average number of species found has been only 19, of which 12—13 are grasses, one only (or none) leguminous, and 5—6 only represent other orders; whilst the average proportions by weight have been—of grasses about 95 per cent., of Leguminosæ less than 0·01 per cent., and of species representing other orders less than 5 per cent.

On the other hand, a plot receiving annually manures such as are of little avail for gramineous crops grown separately in rotation, but which favour beans or clover so grown, has given on the average 4·3 species. Of these 17 in number are grasses, 4 Leguminosæ, and 22 belong to other orders; but by weight the percentage of grasses has

averaged only 65—70, that of the Leguminosæ nearly 20, and that of species belonging to other orders less than 15.

With such very great variations not only in the amount, but in the botanical character of the produce of a crop under any circumstances so complex, it might be anticipated that there would be very great differences in its chemical composition, partly due directly to the supply of constituents by manure, partly to variation in the description of plants encouraged, and partly to the character and degree of development and ripeness of the varying components of the mixed herbage, according to the season and to the manure employed.

With a view to the elucidation of this part of the subject, the dry matter and the ash have been determined in the produce of every plot in every season, the nitrogen in that of all the plots for many of the seasons, and in some cases the amount of it existing as albuminoids has been determined. In selected cases also comparative determinations of "crude woody-fibre" and of crude fatty matter have been made. About 120 complete ash analyses have been executed. And, lastly, samples of the soil of every plot, in some cases at different periods, and in most cases representing the first, second, third, fourth, fifth, and sixth depths of 9 inches, or in all to a total depth of 54 inches, have been collected, and these have been chemically examined in various ways.

It is found that there is a considerable difference in the percentage of dry substance in the produce, and very considerable difference in the percentage of mineral matter (or ash) in that dry substance. There is still greater difference in the percentage of nitrogen in the dry matter, and again, a greater difference still in the percentage of individual constituents of the ash. When indeed it is remembered that a plot may have from 20 to 50 different species growing upon it, each with its own peculiar habit of growth, and consequent varying range and power of food-collection, it will not appear surprising that different species are developed according to the manure employed; and, this being so, that the character and amount of the constituents taken up from the soil by such a *mixed herbage* should be found much more directly dependent on the supplies of them by manure than is the case with a crop of a single species growing separately.

In further illustration it may be mentioned that, not only does the percentage of nitrogen in the produce of the different plots vary considerably, but the average annual amount of it assimilated over a given area is more than three times as much in some cases as in others. Again, the percentage of potass in the dry substance is more than double as much in some cases as in others; whilst the difference in the average annual amount of it taken up over a given area is more than five times as much on some plots as on others, dependent on the supplies of it by manure, and the consequent description of plants, and amount

and character of growth induced. The percentage and acreage amounts of phosphoric acid also vary very strikingly; and so again it is with other mineral constituents, but in a less marked degree.

It will be seen that in the history of so many of what may be called natural rotations, we can hardly fail to learn much that is of interest, not only in reference to the growth of the mixed herbage of permanent grass land, but also something of the relative positions of the different plants that are grown separately, in alternation with one another, in the artificial rotations adopted on arable land.

The botanical results are, moreover, of much independent interest, both by the facts which they already contribute, and by the incentive and direction they may give to future research.

Lastly, the chemistry of the subject will be found to offer many points of interest, in regard to the variation in the percentage composition of the produce, according to the manure applied; to the description of plants developed, and to the character of their development; to the availableness of the constituents artificially supplied; and to the amount and limit of the natural resources of the soil, both actually and compared with the results obtained when individual species are grown in arable culture.

It will be readily understood that the record, and the discussion, of the agricultural, the botanical, and the chemical history of about 20 plots, in 20 different seasons, must involve much detail; and although it is obvious that facts special to any one of the three main divisions of the subject may require for their elucidation reference to those of one or both of the others, it is still believed that it will conduce to clearness, and reduce unavoidable repetition, to maintain the divisions proposed as far as possible.

On the present occasion, Part I only, entitled—"The Agricultural Results," is presented. In Part II, "The Botanical Results," which will next follow, Dr. M. T. Masters, F.R.S., is joint author.

#### XXIV. "On the Comparative Structure of the Cortex Cerebri."

By BEVAN LEWIS, L.R.C.P. Lond., Assistant Medical Officer, West Riding Asylum, Wakefield. Communicated by Dr. FERRIER, F.R.S., Professor of Forensic Medicine, King's College, London. Received June 18, 1879.

(Abstract.)

The object held in view throughout this investigation has been that of instituting an inquiry into the minute structure of the cortex of the brain in a prominent member of the Artiodactyla, and to critically compare the results with those obtained from an examination